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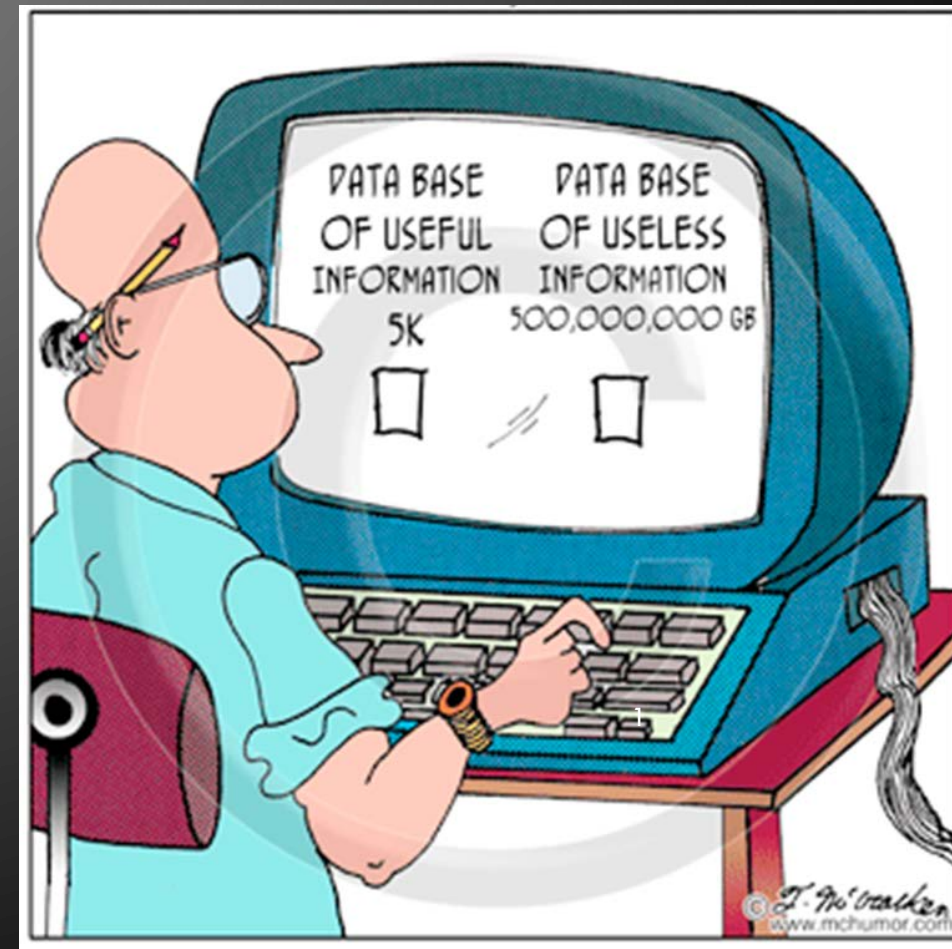
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EDGE^{ip} | INTELLIGENT PROCESSING AT THE SENSOR

MARUTI KUMAR MUDUNURU

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CHICK-KELLER POSTDOCTORAL FELLOW

EARTH AND ENVIRONMENTAL SCIENCES
LOS ALAMOS NATIONAL LABORATORY





**“When oil is
\$100 per barrel,
everyone is an
expert.”**

CEO of an Investment Banking Company
2018 Oil & Gas Executive Conference

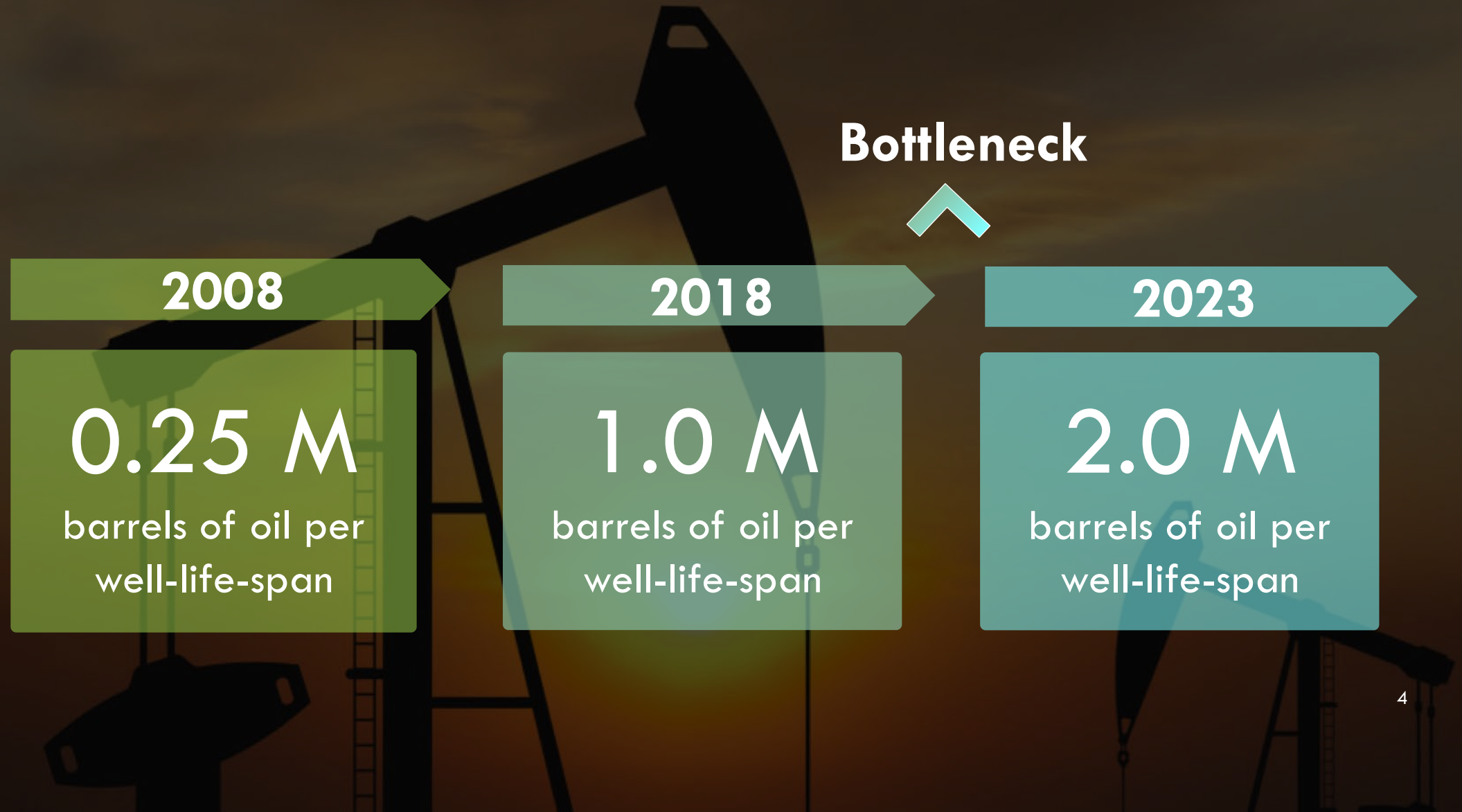
2018 US OIL & GAS ESTIMATES



30,000
wells drilled
each year

1,500,000
wells in
production

CHALLENGE



CUSTOMER KEY PROBLEM: COSTS



Cost of Drilling & Completing Well:
\$5M - \$15M

Time frame: **9-30 days**

Example: “When should I change the drilling bit?”

OPPORTUNITY: WHY AM I DOING THIS?

10%

increase in efficiency
in drilling and
completions

=

\$1M

savings per
well

EXAMPLE: DECISION-DATA FROM SENSORS



What is the real-time composition of my wells?

Multiple sensors deployed.

Steam? Water? Gas? Oil? Drill bits? Flow rate?

Analyzing massive data could take days, weeks.

\$500/hr when well is down.

Need real-time status of wells to increase production!

SOLUTION: REAL-TIME MONITORING & SENSOR DATA PROCESSING

Real-time Monitoring with **EDGEip**



oil and gas wells

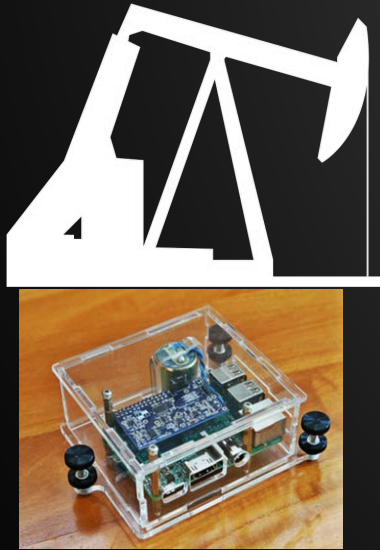


oil-water-gas separation



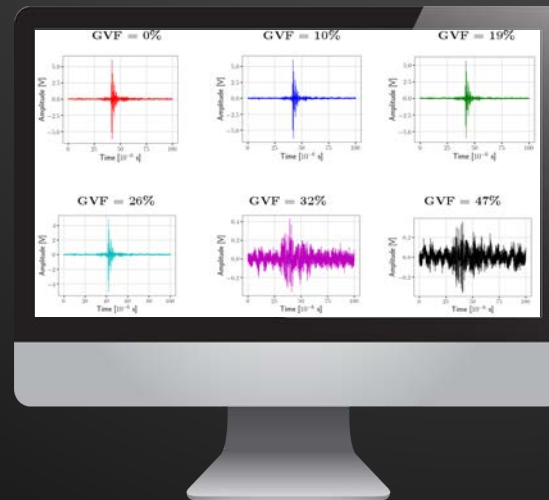
monitoring takes days

SOLUTION: REAL-TIME MONITORING & DATA PROCESSING



Sensor at
the well

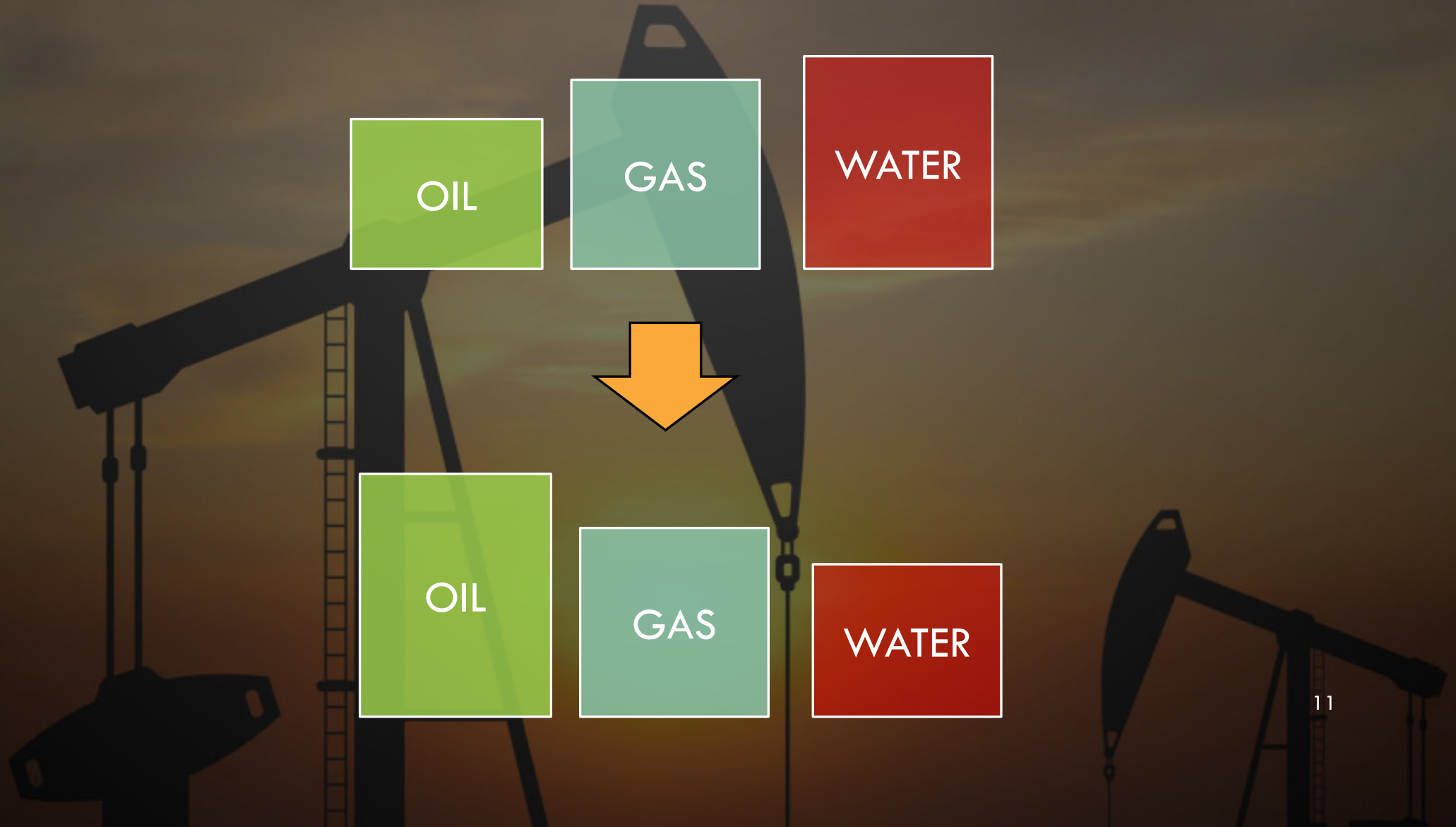
EDGEip



SOLUTION: ACTIONABLE INFORMATION



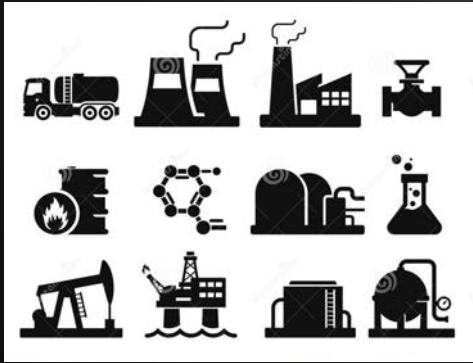
SOLUTION: INCREASE IN PRODUCTION



VALUE PROPOSITION

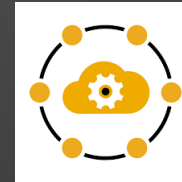
*For oil & gas producers that **do not have real-time information** on wells/production status, installing **EDGE^{ip}** software on their sensors will **reduce downtime, maintenance, and help make more money.***

US MARKET OPPORTUNITY



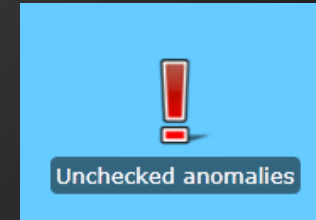
\$9B

Total Market
Enhanced Oil Production and
Well Drilling



\$900M










Total Addressable Market
Data Analytics for Predictive
Maintenance



\$300M

Targeted Segment
Data Processing at Sensor Edge

COMPETITIVE LANDSCAPE

	Customizable	Low Cost	Fast Deployment	Portable Mobile
EDGEip				
Microsoft GE intel				
STARTUPS				

WHY US?

Existing Oil & Gas partnership

High Performance Computing data
processing capabilities

Sensor interface

Access to HUGE datasets

Cutting edge energy-efficient algorithms

BUSINESS MODEL

1

**Sensor already
installed at the
well**

**Software
Customized to
Customer Sensor**

**Subscription
or License**

2

**Before sensor
is installed at a
well**

**Partner with a
Sensor
Company**

**Customize
to New
Sensor**

License

GO TO MARKET FOR COMMERCIALIZATION

2018

Test **EDGE^{ip}**
on lab and field-
data and

Field Trials
with Los Alamos
Seismic Network
(LASN) and Chimayo,
NM Well

2019

Test **EDGE^{ip}** on
Raspberry Pi/Shake
in real-time
geophysical
monitoring at
Chimayo Well

2020

Test **EDGE^{ip}** software
for Oil & Gas well
monitoring with
Producers/Operators/
Sensor Manufacturers

Commercialize tested
EDGE^{ip}

NEXT STEPS: CAPITAL NEEDS

Minimum Viable Prototype: \$100K

Testing Prototype in Field/Sensors: \$500K

Development of Software Interface: \$150K

Field Testing/Deployment: \$2M



Looking for partnerships

- Data sets
- Sensor interface
- Field testing

TEAM & COLLABORATORS: TECHNICAL AND BUSINESS

TECHNICAL

- Maruti Kumar Mudunuru (Data Analytics, Machine Learning, Signal Processing)
- Vamshi Chillara (Collaborator: Sensors, Signal Processing)
- Peter Roberts (Field Deployment Collaborator: Seismic/Geophysical)
- Jeremy Webster (Field Deployment Collaborator: Seismic/Geophysical)
- Satish Karra (Technical Advisor: Data Analytics, Oil & Gas)
- Hari Viswanathan (Technical Advisor: Oil & Gas)
- Gowri Srinivasan (Technical Advisor: Data Analytics)
- Dipen Sinha (Technical Advisor: Sensors, Oil & Gas)
- Paul Johnson (Technical Advisor: Seismic/Geophysical)
- Velimir Vesselinov (Technical Advisor: Environmental Monitoring)
- George Guthrie (Technical Advisor: Oil & Gas, Seismic/Geophysical)

BUSINESS

- Don Winter (Investment Mentor)
- Paul Short (Investment Mentor)
- Don Hickmott (Business Development Mentor)
- Molly Cernicek (Business Development Mentor)

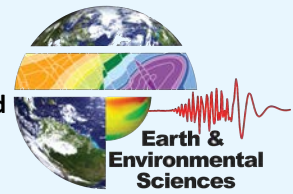
TECHNICAL MILESTONES

- Oil & Gas
 - MPA-11
- Geophysical
 - EES-17
- Environmental
 - EES-16

Extracting eruption dynamics signatures of CO₂-driven cold-water geysers using machine learning

Maruti Mudunuru¹ (maruti@lanl.gov), Paul Johnson¹, Satish Karra¹, Omar Marcillo¹, Andrew Delorey¹, and George Guthrie¹

¹Earth and Environmental Sciences, Los Alamos National Laboratory.



ABSTRACT

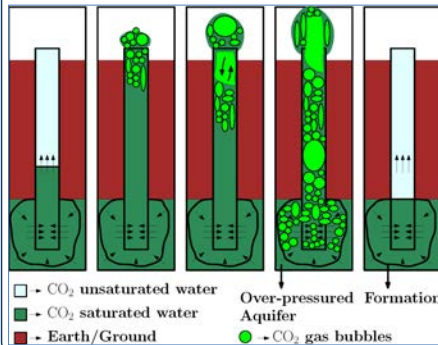
Thermally driven geysers (such as Yellowstone) are characterized by frequent eruptions of liquid water and steam. Another subsurface system capable of producing periodic eruptions (similar to thermal geysers) is CO₂-driven cold water geysers. They erupt for over 24h at a time with relatively high velocity CO₂-driven discharge from wellbores. Growing interest in geologic carbon storage has brought attention to CO₂-driven cold water geysers because of its similarity to high velocity wellbore leakage process. In the CO₂-driven cold-water geysers, CO₂ (gas) evolves by the pressure reduction (flashing) of CO₂-rich fluids. Once the internal pressure of CO₂ (aqueous) becomes greater than that of the surrounding fluid, CO₂ separates from the fluid causing bubbles to nucleate, grow, and coalesce. Hydrostatic pressure reduction resulting from increasing CO₂ gas volume fraction enhances expansion of CO₂ bubbles leading to the eruption. In this poster, we present a feature extraction framework to identify a set of precursors to understand the eruption dynamics from time-series signals (seismic, acoustic, pressure, water depth, temperature, etc.) using machine learning. To be specific, we extract precursors that characterize the periodic eruption events from noisy data sets through time-series feature engineering and noise-filtering methods. These precursors can help in better understanding of the behavior of eruption times of CO₂-driven cold-water geysers.

Problem Description

- Substantial concern over the potential impact of groundwater resources in the case that a CO₂ sequestration reservoir were to leak
- For leakage monitoring in large areas, one needs:
 - To identify leaks quickly,
 - To discern leakage signals vs anthropogenic noise from large datasets, and
 - To have a cost-efficient sensing system
- Need a generic and robust framework to identify precursors
- Framework should be fast, scalable, and applicable for various applications

Objective

Discover precursors in noisy seismic and infrasound signals related to the CO₂-driven cold-water geyser at Chimayó geyser, NM

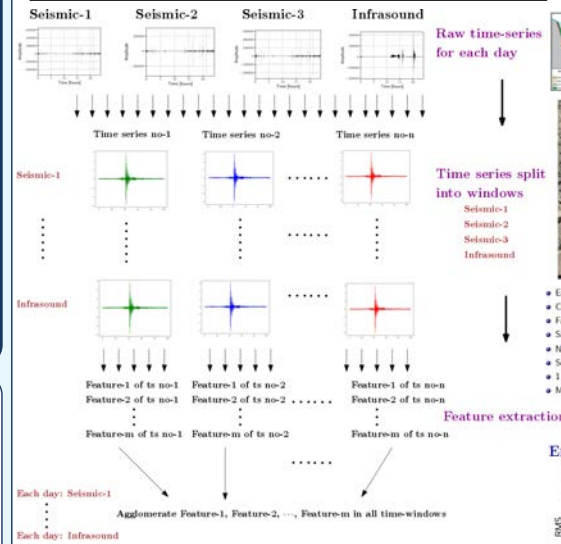


Acknowledgments

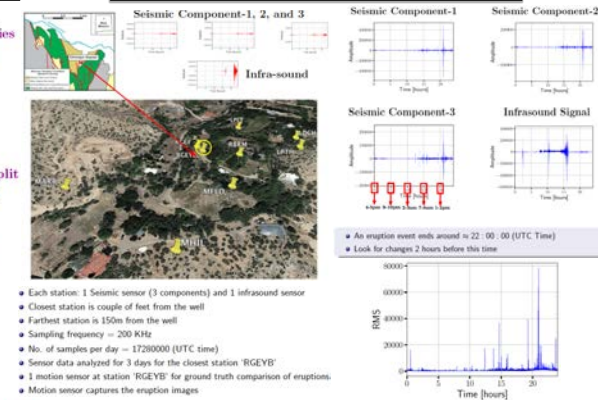
The authors thank Chick-Keller Postdoctoral Fellowship, UC/LANL Entrepreneurial Postdoctoral Fellowship, and LDRD-DR on Critical Stress for support

Eruption Dynamics Precursor Extraction using Machine Learning

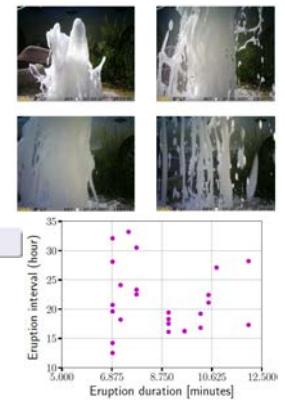
Hierarchical scalable time-series feature extraction



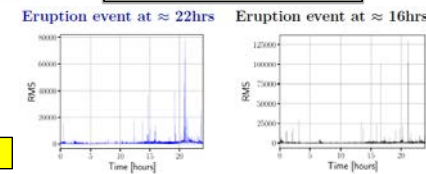
1. Chimayó geyser and sensor locations, NM



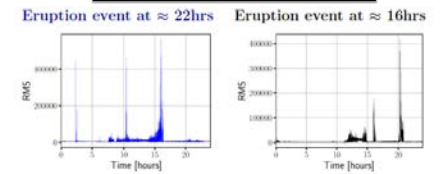
2. Sensor data information



3a. RMS of seismic signals



3b. RMS of infrasound signals



Noise reduction in extracted time-series features

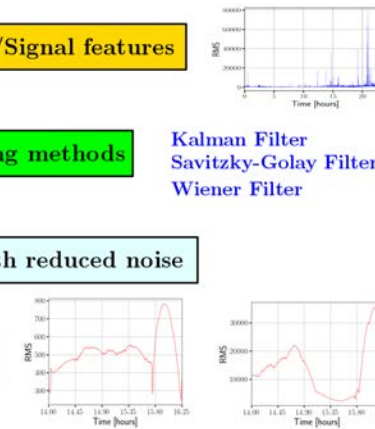
Time-series/Signal features

Noise filtering methods

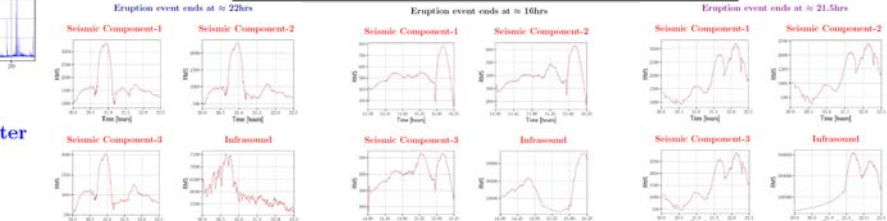
Kalman Filter
Savitzky-Golay Filter
Wiener Filter

Features with reduced noise

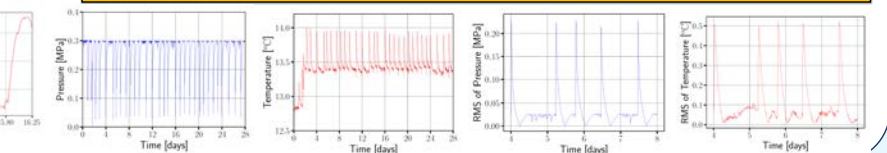
Precursors

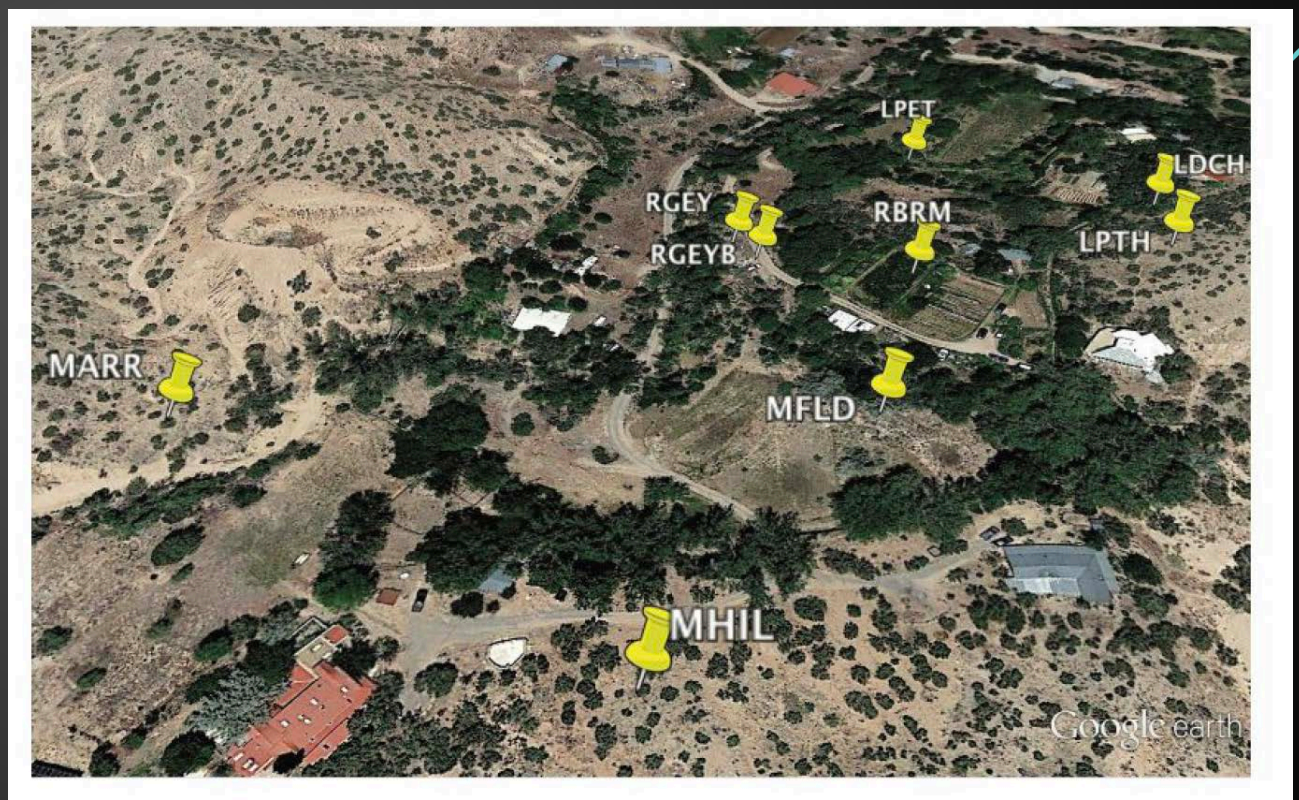
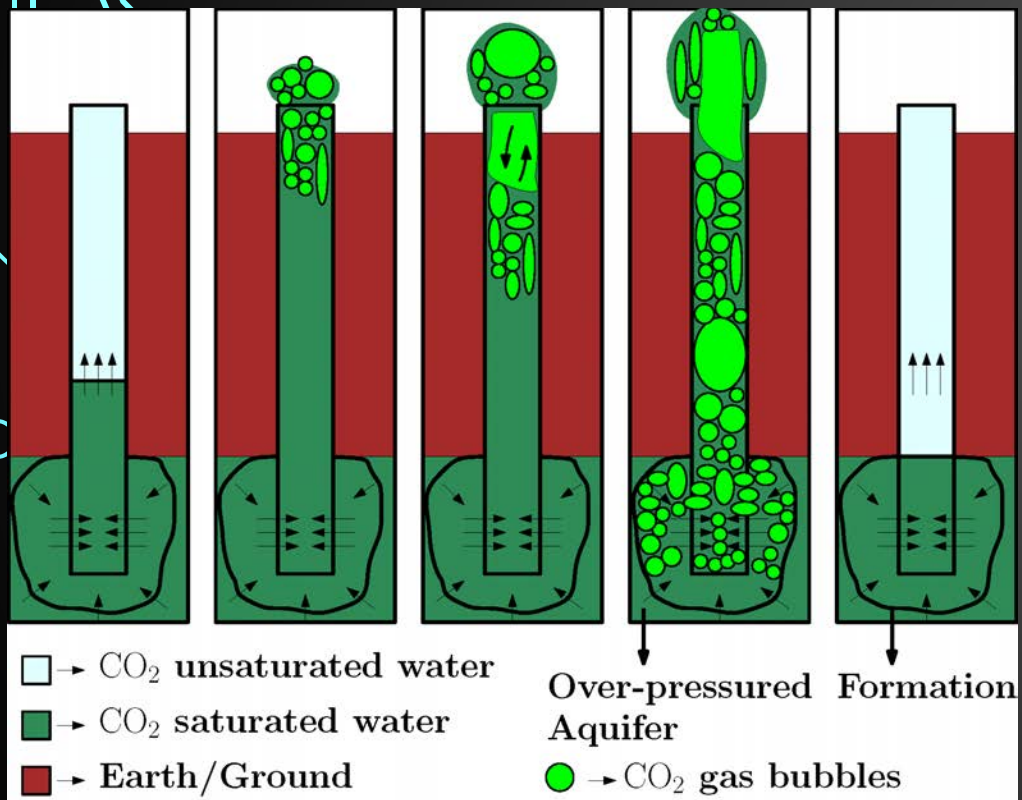


4. Precursors related to seismic and infrasound signals



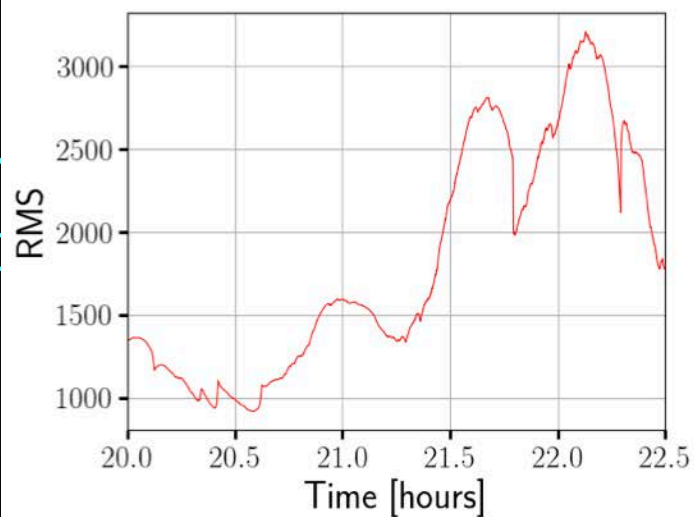
6. Pressure and temperature signals and corresponding eruption event precursors



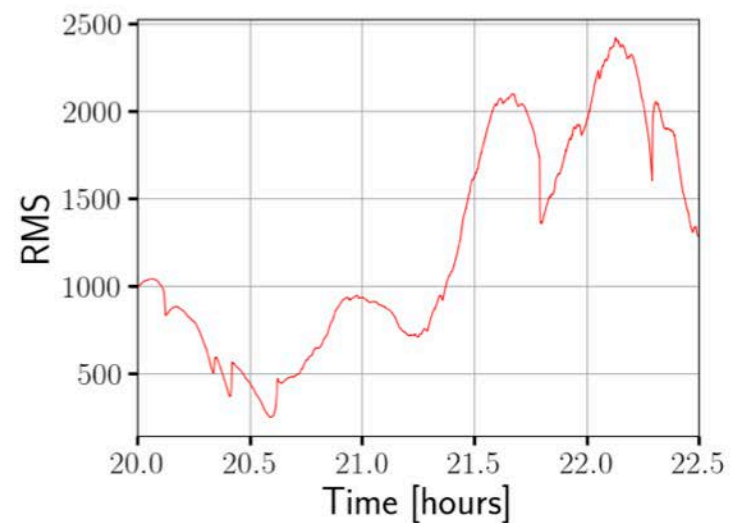


Eruption event ends at ≈ 21.5 hrs

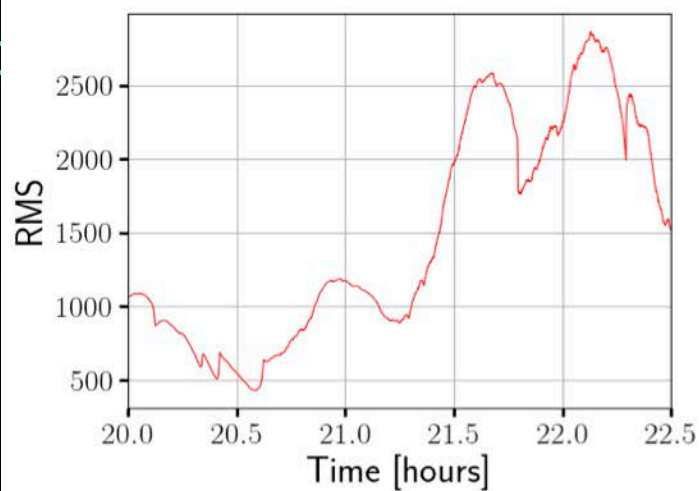
Seismic Component-1



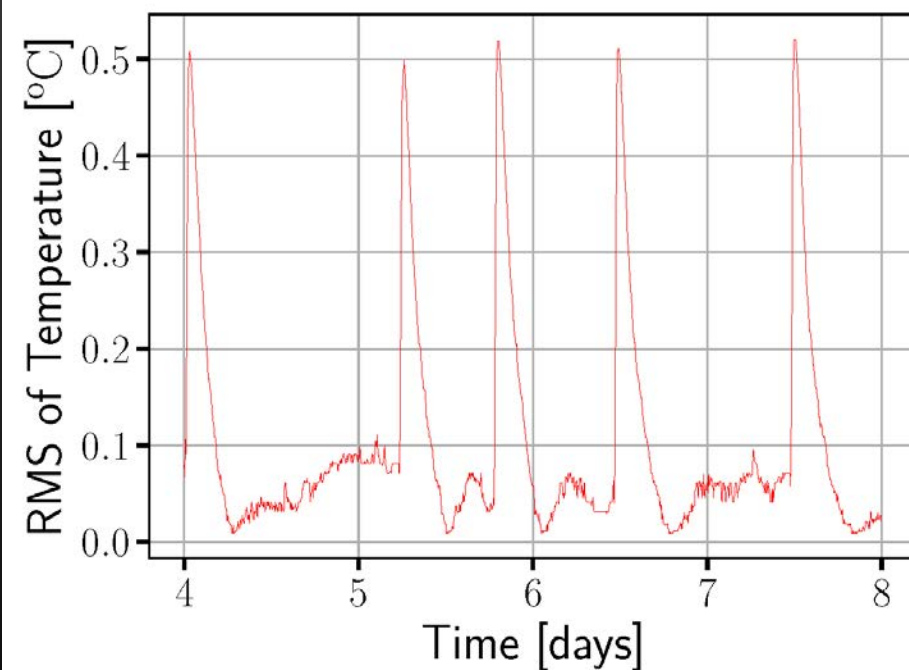
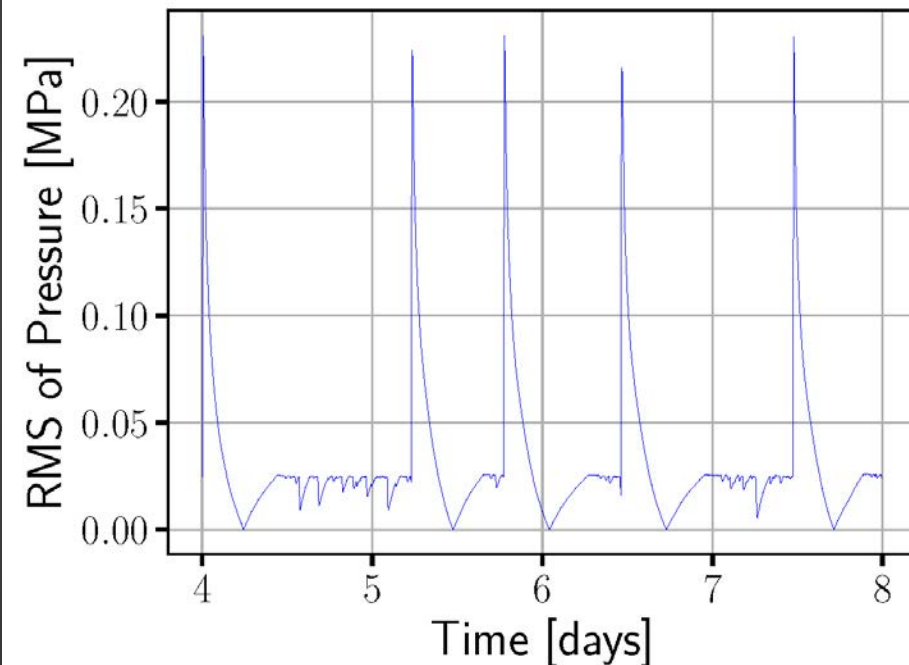
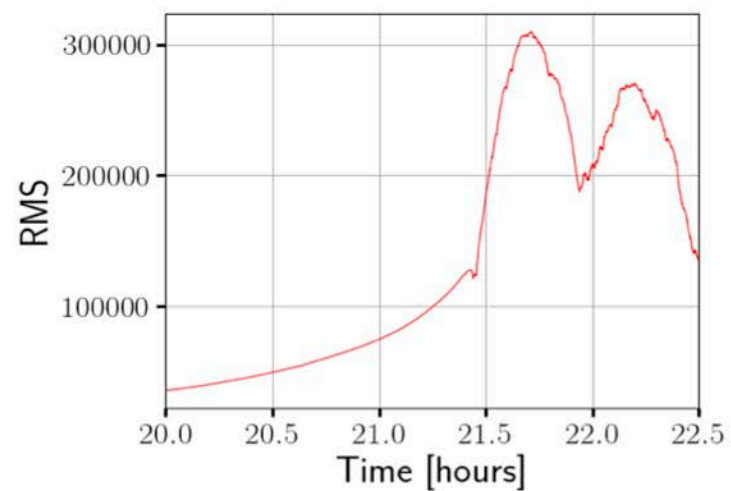
Seismic Component-2












Seismic Component-3



Infrasound



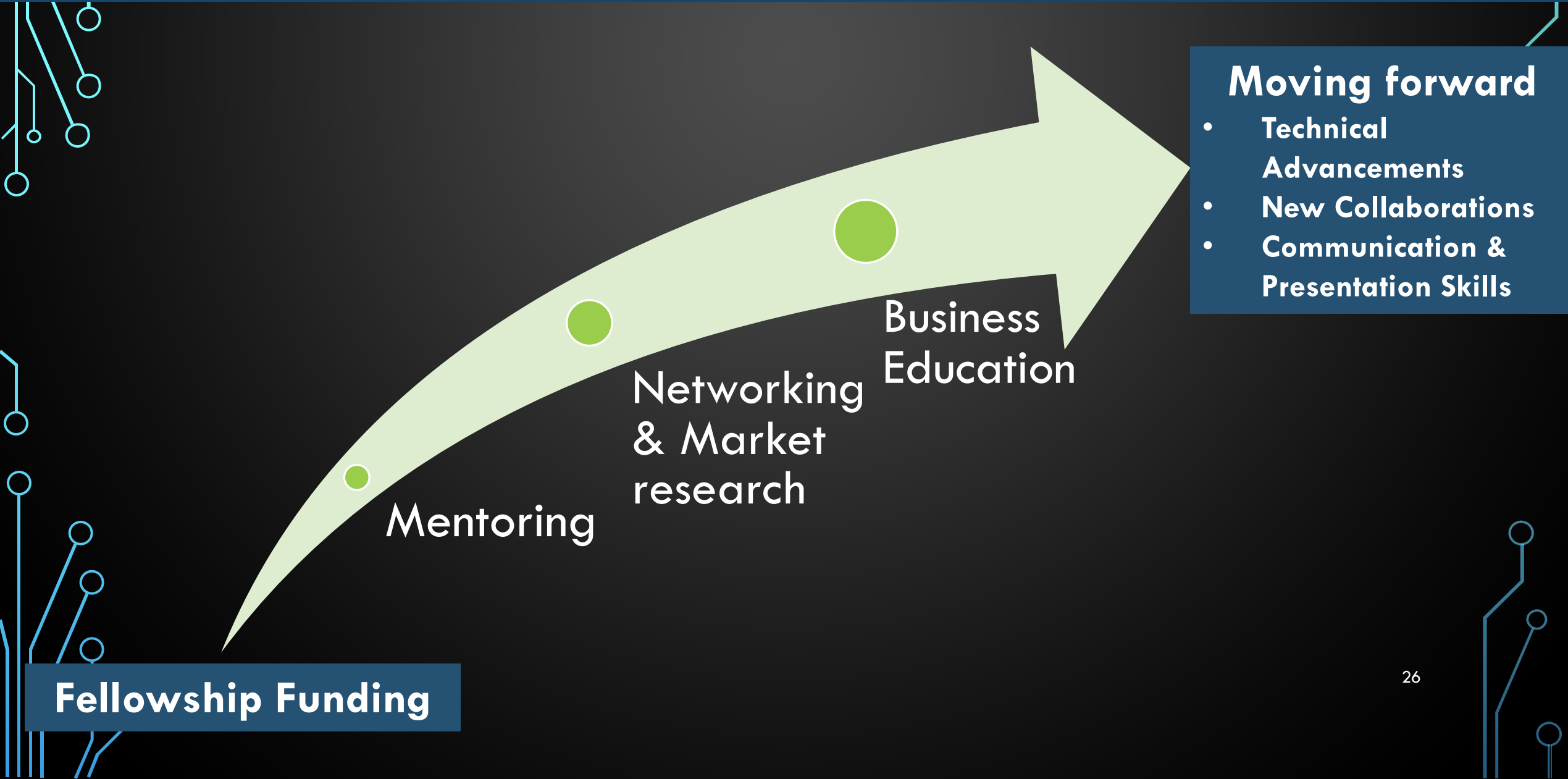
BUSINESS MODEL CANVAS

Key Partners  <ul style="list-style-type: none">1. Sensor Manufacturers2. Oil & Gas Service Companies3. Process Monitoring Companies	Key Activities  <ul style="list-style-type: none">1. Sensor-Software Interfacing2. Testing EDGE^{ip} in field3. Small-scale field deployment Key Resources  <ul style="list-style-type: none">1. Packaging2. Virtual testing with various field datasets3. Copyright disclosure of EDGE^{ip}	Value Propositions  <p><i>For small and medium-scale oil & gas producers that do not have real-time information on wells/production status, installing EDGE^{ip} software on their sensors will reduce downtime, maintenance, and help make more money.</i></p>	Customer Relationships  <ul style="list-style-type: none">1. Direct interaction with sensor manufacturers2. Service for increased business value Channels  <ul style="list-style-type: none">1. Service companies2. IoT sensor/device manufacturers3. People working in field	Customer Segments  <ul style="list-style-type: none">1. Well Production and Fluid Composition2. Drilling & Completions3. Frac and Seismic Activity Monitoring4. Spill, Environment, and Contaminant Monitoring5. Pipelines and Corrosion Detection
Cost Structure  <ul style="list-style-type: none">1. Prototype testing for virtual datasets (e.g. production, drilling and completions, etc)2. Software UX/UI/App3. Sensor interfacing and testing it on field4. Field deployment and small-scale trials			Revenue Streams  <ul style="list-style-type: none">1. Subscription2. Licensing3. Software as standalone product	

CUSTOMER DISCOVERY & MARKET RESEARCH



HOW I BENEFITED FROM THE FELLOWSHIP?



Thank You!

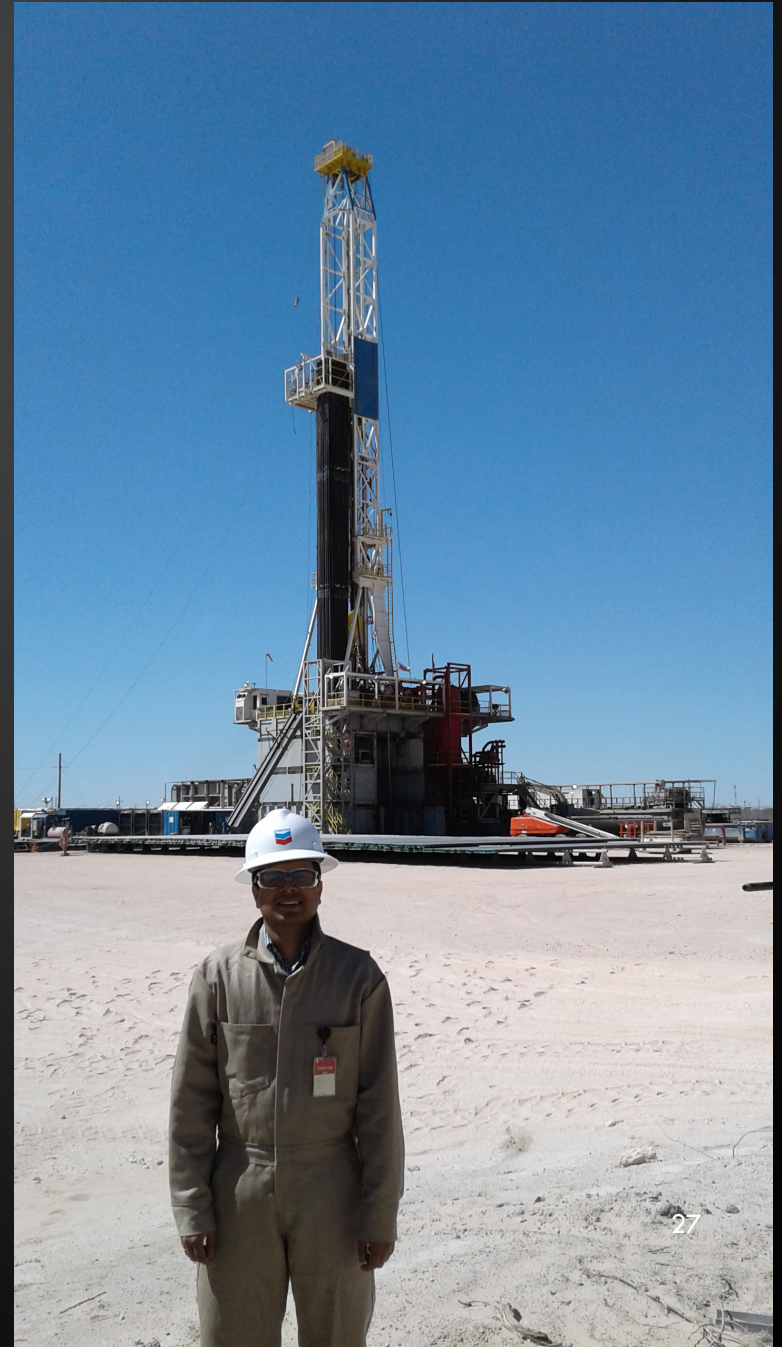
MARUTI KUMAR MUDUNURU

Earth and Environmental Sciences

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Phone: 505-667-1049



BACK-UP SLIDES

CUSTOMER KEY PROBLEM: PRODUCTION STATUS

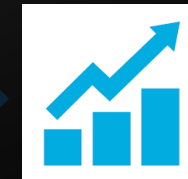


What's my well production?
Any report-by-exception cases?

- **Steam** or **Water** or **Gas** or **Oil**?
- What is the real-time composition of my well?
- A **loss of around \$500/hour** is incurred if a well is not operational
- Analyses of wells using existing workflows take **days to weeks** of time
- Additional **losses** are incurred if a well is **producing < 100-400 barrels of oil/day**

*"I hit a bottleneck in oil & gas production!!!
Can anyone help me increasing production?
Can anyone provide real-time status of my well production?"*

- **CEOs, Senior VPs, Investment Bankers, Business Executives @ DUG Executive Conference**
- **Senior Manager, Major Oil & Gas Company**
- **Blue Hill Research on Oil & Gas Production**



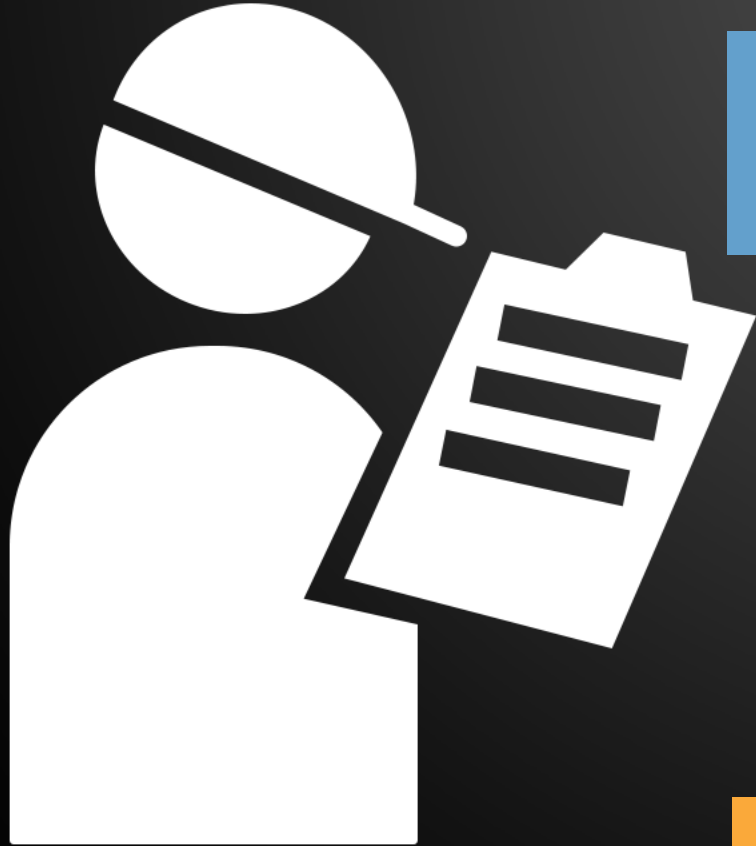
CUSTOMER KEY PROBLEM: DRILLING COSTS

When should I change the drilling bit?

**Cost of Drilling & Completing Well:
\$5M - \$15M**

5000-7000ft deep well | 7000-10000ft horizontals
50 fracture stages. | 20-24 pump trucks of 2000HP
10-15 million gallons of water
10-20 million pounds of proppant/sand

Time frame: 9-30 days



SOLUTION: REAL-TIME MONITORING & DATA PROCESSING



Oil & Gas Wells

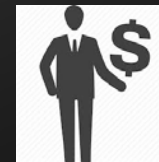
How about we monitor production status here in real-time?



Oil-Water-Gas Separation

“Current status of monitoring oil & gas production takes days of time, we want a system that does this in near real-time”

Senior VP, Major Oil & Gas Company, @ DUG Executive Conference



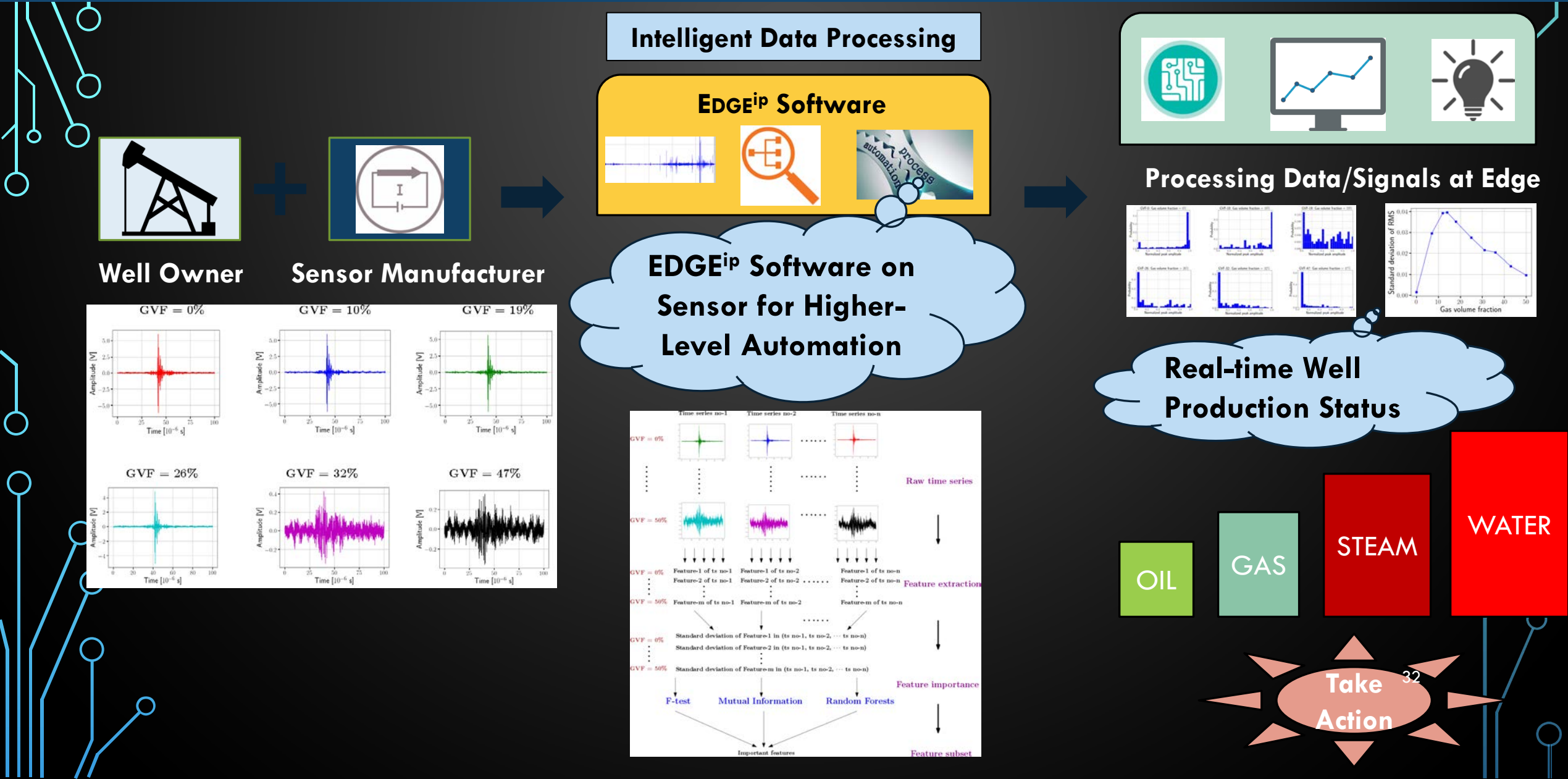
OIL

GAS

STEAM

WATER
31

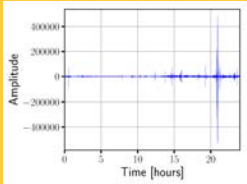
SOLUTION – PRODUCT --- PROCESSING DATA AT EDGE



SOLUTION: INCREASED PRODUCTION. REDUCED COSTS.

EDGE^{ip} Software

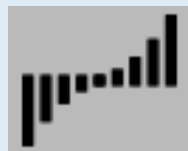
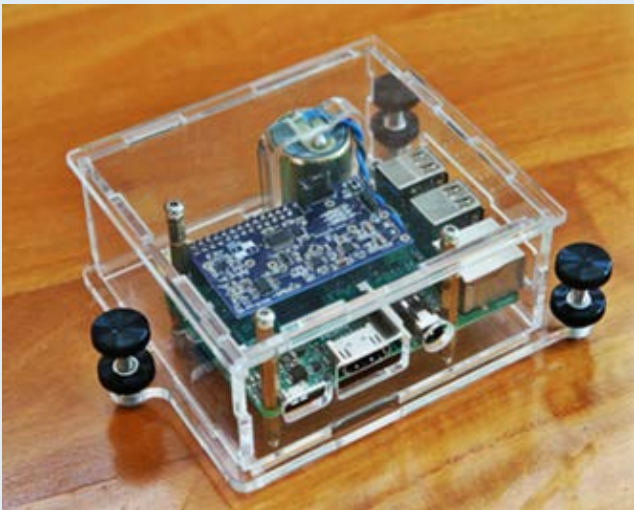
TB of Raw Signals



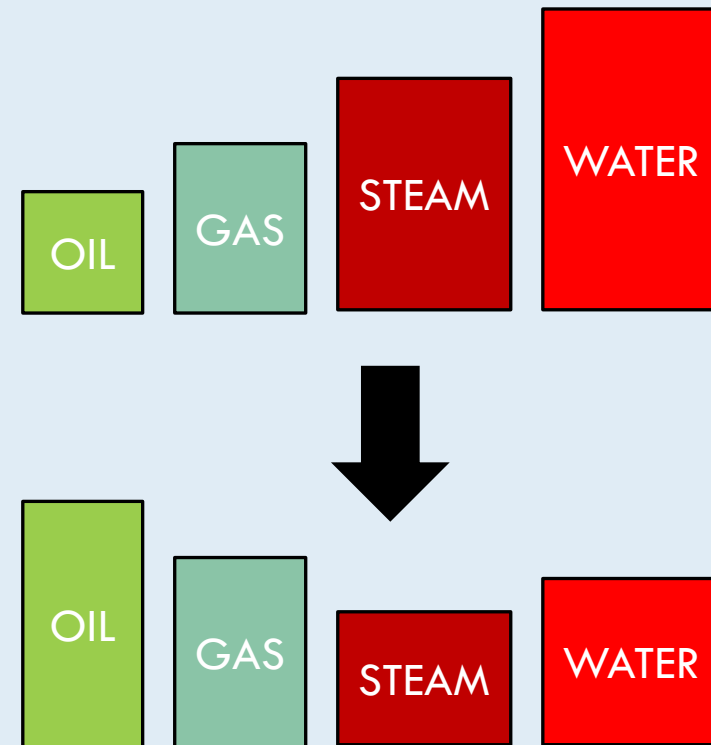
Actionable Information in MB



Product: EDGE^{ip} Software on Raspberry Pi



- **Massive Cost Reduction, Savings, Reduced Downtime**
 - Energy-efficient processing (~power to charge a mobile)
 - Actionable information
 - A 10% increase in drilling and completions efficiency results in savings of \$1M/well
 - 10 % increase in production (~5000 oil barrels/year)



GO TO MARKET

2018

March

April

May

June

July

Testing **EDGE^{ip}** software for lab-data and field-data

Field Trials of **EDGE^{ip}** software with Los Alamos Seismic Network (LASN) and Chimayo Well, NM

2018

August

Sep

Oct

Nov

Dec

Forward Deployment: Tested **EDGE^{ip}** software on Raspberry Pi/Shake for real-time geophysical monitoring at Chimayo Well, NM

2019

Jan

Feb

March

April

May

Forward Deployment: Test **EDGE^{ip}** software for Oil & Gas well monitoring with Producers/Operators/Sensor-Manufacturers

Launch the tested **EDGE^{ip}** software for commercialization (3-6 months)

PRODUCT STATUS AND VALUE PROPOSITION

- **Current product status**

- Testing **EDGE^{ip}** software
- Testing with a potential customer to train the algorithm
- Datasets
 - Oil & Gas
 - Seismic/Geophysical
 - Environmental

BUSINESS MODEL

- **Who Will We Sell To?**

- Sensor Manufacturers
- Monitoring Companies
 - Oil & Gas producers
 - Seismic/Geophysical/Environmental
- Subscription/License

- **Partnership with Sensor/Processor Product Company**

- Oil Majors
- Raspberry Pi Company
- RaspberryShake Company

1. Sensor already installed at the well

Software Customized to Customer Sensor

Subscription or License

2. Before sensor is installed at a well

Partner with a Sensor Company

Customize to New Sensor

License